San Luis Obispo County
Los Osos Wastewater Project Development

TECHNICAL MEMORANDUM

PARTIALLY MIXED FACULTATIVE POND OPTIONS

FINAL DRAFT
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PARTIALLY MIXED FACULTATIVE POND OPTIONS

1.0 INTRODUCTION

Partially mixed facultative ponds (PMFPs) are one of the potential treatment alternatives that passed the fine screening process, as described in the Viable Project Alternatives Fine Screening Analysis (Carollo Engineers, August 2007). There are several proprietary and non-proprietary variations on facultative ponds commonly used in the industry. The purpose of this technical memorandum (TM) is to evaluate and compare different types of facultative pond treatment alternatives that could be used for wastewater treatment in Los Osos in greater detail than the Fine Screening Analysis.

The information developed in this TM will be used as 1) the basis for evaluating the impacts of this treatment process for the environmental review document; 2) and the basis for further developing this process alternative and refining the construction cost estimates. Ponds are not the only process being considered, as the Fine Screening Report also evaluated oxidation ditches and Biolac as feasible treatment options.

2.0 PMFP CHARACTERISTICS AND CONSIDERATIONS

PMFPs incorporate biological processes that oxidize organic material and physical settling of organic and inorganic solids. Facultative organisms function with or without dissolved oxygen. Facultative ponds are generally aerobic near the surface and anaerobic near the bottom where solids are digested.

There is a continuum of alternatives for PMFPs where, generally, energy costs are traded for land area required. On the low-energy, land-intensive end of the spectrum are ponds where wastewater is treated with almost no input of energy in ponds with long detention times. At the other extreme are aerated ponds, which require much more energy, but have smaller land area requirements. These ponds have many of the same characteristics as extended aeration technologies such as Biolac™. In the middle of the spectrum, some ponds systems combine facultative and aerated cells.

Facultative ponds are usually designed in a multicellular configuration in order to reduce hydraulic short-circuiting. The first cell is designed to settle influent solids, and subsequent cells are designed to maximize BOD degradation.

Because of their large volumes, PMFPs are fairly resistant to shock in either hydraulic or organic loading. Ponds can be designed with shallow side slopes of 3:1, which means that additional hydraulic loading can be more easily accommodated since the upper portion of the ponds has a larger volume than the lower portions.

Increased earthwork and land costs need to be balanced with equipment and energy costs to determine the preferred alternative. The Regional Water Quality Control Board (RWQCB) will likely require pond bottoms be lined to prevent infiltration of wastewater into the soil beneath the ponds. This requirement will have a greater impact on the cost of pond systems with larger footprints.

Pond systems are subject to the influence of temperature and weather, and as a result, effluent quality can be difficult to control. Yet, an effluent quality of less than 30 milligrams per liter (mg/L) BOD is generally achievable as proven by numerous facilities throughout the country. Due to algal growth, pond effluent TSS can exceed 30 mg/L and may require additional treatment. Pond facilities are sometimes granted permit effluent limits up to 50 mg/L TSS, which is considered "equivalent to secondary treatment". Additionally, ponds can remove some nitrogen, but not enough to meet anticipated limits of less than 7 mg/L total nitrogen for the Los Osos Wastewater Project.

In each type of pond, solids are settled and anaerobically digested within the pond, reducing the need for sludge handling and hauling. This is a significant benefit of PMFPs. It is estimated that only 3 to 5 percent of solids are non-degradable and will have to be removed from the ponds, resulting in a frequency of sludge removal on the order of years (Rich, 1980). Bacterial additives that enhance solids digestion are available for purchase, and some pond managers using these additives report not removing solids for decades. Monitoring of the sludge depth is recommended every couple of years to verify that it is not impacting effluent quality. Removal of the solids is assumed to occur at 20-year intervals, so ponds should be designed to provide adequate volume for up to approximately 20 years of sludge accumulation, which is approximately equivalent to an extra two feet of freeboard.

2.1 Labor

After discussions with pond utility managers, the labor required for a PMFP facility was revised downward from the Fine Screening Analysis estimate of 2.0 full-time equivalents down to 1.5 full-time equivalents for all types of PMFPs.

2.2 Division of Safety of Dams Jurisdiction

The California Division of Safety of Dams regulates the storage of large volumes of water. However, they generally allow water stored as part of a wastewater treatment facility to fall outside of their jurisdiction, as stated in their Statutes and Regulations:

a) Notwithstanding any other provision, subject to subdivision (b), the requirements for state regulation and supervision of safety of dams, as contained in this division, shall not be applicable to waste water treatment and storage ponds constructed as a part of a waste water control facility.

b) This section applies to those ponds specified in subdivision (a) only after the governing body of the city, county, district, or other agency which operates the waste water control facility adopts a resolution which (1) finds that the ponds have been constructed and operated to standards adequate to protect life and property, and (2) provides that the city, county, district, or other agency shall supervise and regulate the design, construction, operation, enlargement, replacement, and removal of the ponds after the effective date of the resolution.

Therefore, it is not anticipated that a permit from the Division of Safety of Dams will be required to construct ponds for the Los Osos wastewater project.

2.3 Additional Treatment

In data gathered from many pond installations throughout the country, PMFPs usually do not meet the low nitrogen or suspended solids (from algae) permit limits expected for a Waste Discharge Requirement issued by the RWQCB without additional treatment. Additionally, like the other treatment processes being considered, PMFPs alone do not remove all pathogens so disinfection is required. Due to seasonally variable effluent quality, ponds with additional treatment can be difficult to size and operate. Additional steps to remove nitrogen, algae and pathogens from the effluent are discussed in the following sections.

2.3.1 Nitrogen Removal

PMFP processes provide some degree of nitrogen removal, although not enough to satisfy the low limits that are anticipated in a Waste Discharge Requirement issued by the RWQCD. Total nitrogen limits of 7 mg/L are anticipated for effluent that is disposed of, or reused in the Prohibition Zone. However, if some of the effluent is used for agricultural irrigation, or disposed of on sprayfields, then it may not be necessary to provide nitrogen removal for the entire waste stream. Nitrogen is allowed in reclaimed water if it is applied at agronomic rates. The need for nitrification and denitrification was discussed in Section 4.6 of the Fine Screening Analysis.

2.3.1.1 Nitrification

Nitrification is the conversion of ammonia and organic nitrogen to nitrate, which is a necessary step prior to denitrification, which removes nitrogen from the wastewater altogether. No pond alternative consistently nitrifies year-round. For any of the pond alternatives being considered, additional processes will likely be necessary to reduce the ammonia in the plant effluent to meet regulatory limits for nitrogen. The Fine Screening Report identified additional nitrification using a nitrifying trickling filter. Another option is a nitrifying rock filter that uses the same principles of treatment (attached growth of nitrifying bacteria and other organisms), which may be marginally less costly. The addition of the nitrification process and cost is common to all pond alternatives. Therefore, the costs of alternative nitrification processes are not presented in this comparison of secondary treatment costs.

2.3.1.2 Denitrification

Denitrification is the conversion of nitrate to nitrogen gas, a process that removes nitrogen from the wastewater stream. The PMFPs described in this TM do not produce a denitrified effluent. Denitrification filters would have to be added on to the end of any treatment train in order to meet the low nitrogen requirements that are anticipated for the project (total nitrogen < 7 mg/L). The Fine Screening Report presented costs for the addition of denitrification filters. These costs are not presented herein as they are add-on processes and costs common to all pond alternatives.

2.3.2 Removal of Algae

Algae growth in PMFPs can cause exceedance of the discharge effluent solids concentration. Algae naturally grow on open water areas such as wastewater ponds. The algae perform a useful function in oxidation ponds by introducing more oxygen into the water through the algal respiration process. This oxygen is crucial to reduction of organics (biochemical oxygen demand [BOD]) and odors. However, algae generated in the ponds must be removed from the effluent to meet discharge and reuse requirements. Removal of algae generally requires filtration (sand or membrane) or dissolved air flotation (DAF) thickeners. Other methods of controlling algae growth are complete mixing of the ponds through aeration or covering the ponds to prevent light exposure. Algal growth may be prevented by covering the pond area corresponding to the last 5 days of detention time, rather than the entire pond area.

3.0 POND ALTERNATIVES

There are several pond alternatives being evaluated in this TM. All the alternatives can be categorized as partially mixed facultative ponds, or aerated ponds. The alternatives include: the Advanced Integrated Pond System, the Dual Power Multicellular Aerated Pond and the Air Diffusion Systems Ponds. Ponds can provide treatment without aeration, however, this required large areas of land. For completeness of this TM, non-aerated ponds are discussed as well, although they are not considered feasible for Los Osos and were eliminated in the Rough and Fine Screening Reports. All of the pond alternatives presented would require additional treatment for nitrogen removal and possibly a treatment process to remove or suppress algae growth in order to meet anticipated WDR limits for nitrogen and TSS, respectively.

3.1 Non-Mechanically Aerated Facultative Ponds

Non-mechanically aerated facultative ponds (facultative ponds) were previously eliminated from consideration because of their large land area requirements. However, they are discussed in this TM because they provide the basis for the technology that is used by the PMFP alternatives.

In non-mechanically aerated facultative ponds, dissolved oxygen is supplied by algae living within the pond and atmospheric transfer through wind action. They also rely on diurnal temperature variations to provide some degree of vertical mixing. Because oxygen transfer depends on natural processes and is not augmented mechanically or by other means, the rate of BOD degradation is slower than for mechanically aerated facultative ponds. Facultative and anaerobic reactions need more time than aerobic reactions to provide the same degree of treatment. Additionally, facultative ponds are shallower than mixed ponds because oxygen is only present near the surface. The shallow depth and longer hydraulic retention time necessitate a larger footprint to accommodate the same flows. The detention time of facultative ponds is typically over 120 days.

3.2 Partially Mixed Facultative Ponds

Mechanically aerated facultative ponds usually make use of mechanical surface aerators or other equipment to introduce oxygen into the water column. The agitation of the ponds helps to prevent algae formation and keeps solids in suspension so that contact between microbes and dissolved organics is maximized. Partially mixed facultative ponds provided with adequate aeration can be deeper and have a smaller footprint than facultative ponds. However, use of mechanical aerators or blowers increases energy costs.

There are many ways to design PMFPs. Three configurations are discussed in this section.

3.2.1 Dual Power Multicellular Aerated Pond (DPMC)

The DPMC configuration (Figure 1) is modeled after the system developed by Dr. Linvil Rich, a professor at Clemson University and is sometimes called a “Rich” Pond. The first cells are aerated at 30 hp/MG to keep solids in suspension and mix oxygen into the water. The retention time of these cells is at least 1.5 days. The complete mixed cells are followed by a series of partially mixed cells which allow solids to settle, but are aerated at a minimum level of 5 hp/MG to provide an aerobic cap for further treatment, to prevent odors and reduce algae growth. Typically, there are three such cells and each has a hydraulic residence time of at least one day. Solids accumulate in the partially mixed cells, particularly the first in the series.

The City of Hollister operates DPMC ponds. They successfully meet their TSS and BOD limits of less than 60 mg/L each. Lower limits can clearly be achieved as in a DPMC installation in Berkeley County, South Carolina effluent was reported as containing 25 mg/L TSS and a BOD of less than 20 mg/L (Rich, 2005).

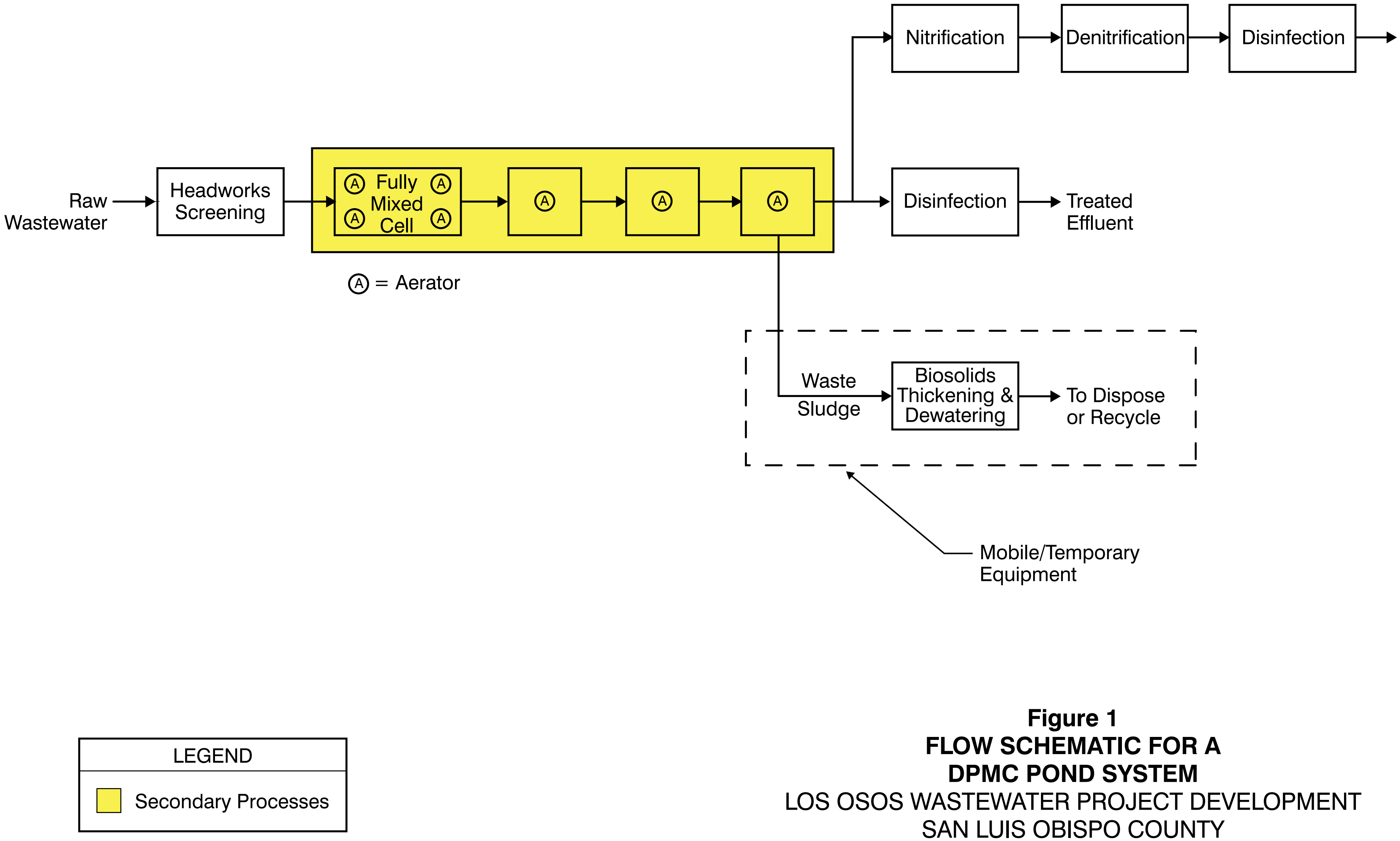

Figure 1
FLOW SCHEMATIC FOR A
DPMC POND SYSTEM
LOS OSOS WASTEWATER PROJECT DEVELOPMENT
SAN LUIS OBISPO COUNTY

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3.2.2 Advanced Integrated Pond System (AIPS)

The Advanced Integrated Pond System (AIPS) involves an initial deep facultative pond with an aerobic cap provided by surface aerators followed by more shallow ponds that are also mechanically aerated. The initial facultative pond has a sculpted bottom to encourage settling while allowing aeration. Influent is piped into the pond from the bottom, where solids settle. The advantage of this system configuration over DPMC is that oxygen is not consumed to degrade settleable BOD (which degrades anaerobically at the pond bottom), so energy costs are lower. Figure 2 shows the AIPS configuration. The first pond is mixed enough to agitate the top three feet, but not enough to prevent settling of solids. AIPS has lower energy and higher land area requirements than DPMC.

The Wallace Group operates a 0.35 million gallons per day (mgd) AIPS Pond for the Woodlands Mutual Water Company. They have not had problems with odors, and do not anticipate removing solids from the ponds for 20 years. The pond effluent TSS is 50 mg/L, consisting mostly of algae. The pond effluent is treated by microfiltration before reuse, which reduces the TSS to less than 10 mg/L. The BOD is 10 mg/L measured after filtration. They do not have to meet nitrogen limits since their effluent is reused for golf course irrigation.

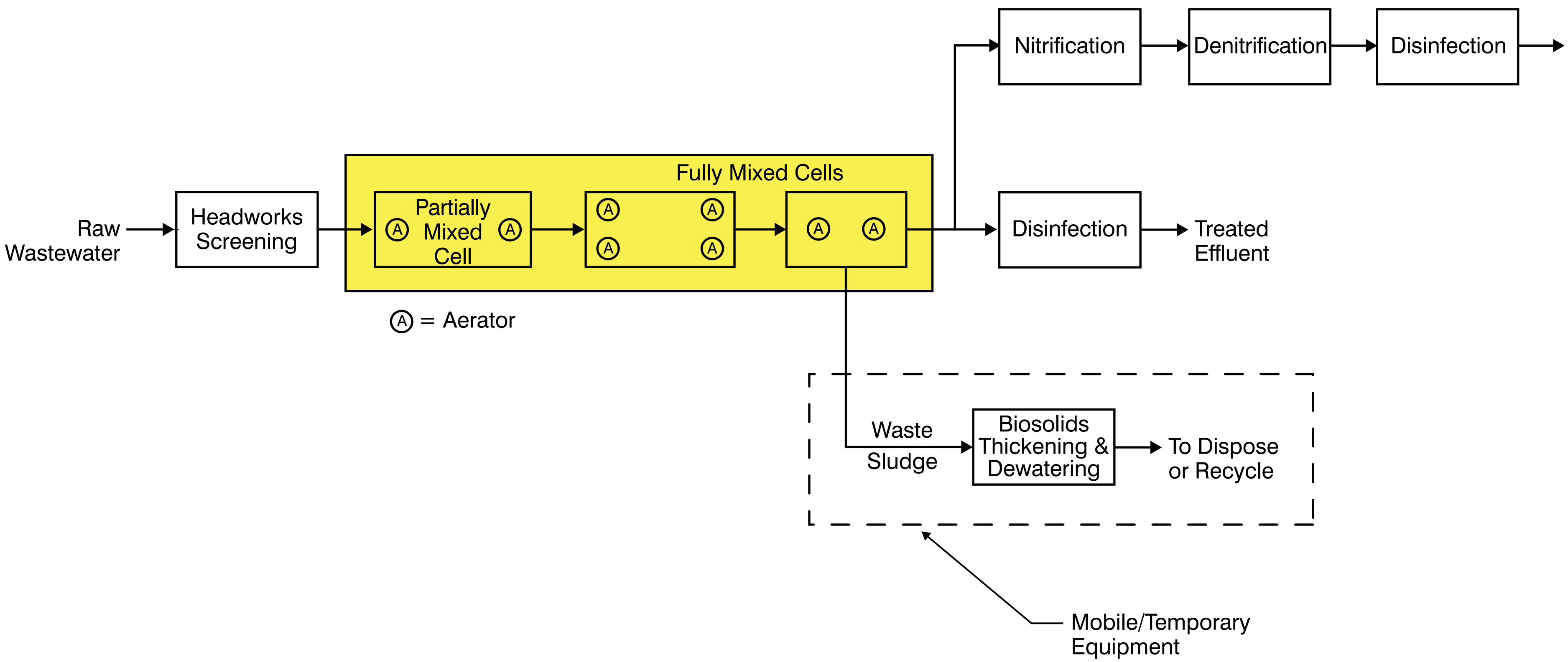
3.2.3 ADS/Nelson Aerated Pond System

One proprietary technology employing mechanically aerated ponds is the Air Diffusion Systems (ADS) pond (Figure 3). This technology is also known as the Nelson System, since Nelson Environmental, who pioneered the pond system, uses ADS equipment. Oxygen and mixing are provided by fine bubble diffusers that are laid out at the bottom of the ponds. This ensures that oxygen is vertically distributed throughout the pond. In addition, aeration discourages algal growth on the pond surface.

A conceptual proposal was solicited from ADS. Their proposed system includes three ponds, the first of which is for settling, the second for BOD degradation and the third with an aerated rock filter for nitrification. However, only the first two ponds were considered in the cost analysis for this TM so that all three pond systems can be compared on the same basis. All three pond alternatives discussed in the TM would require an additional nitrification step.

ADS provides a limited guarantee that their system can meet a monthly effluent BOD less than 30 mg/L, TSS less than 30 mg/L and ammonia less than 7 mg/L for five years.

ADS also provided a list of utility managers using its product. The managers interviewed were all positive about the operation of their ponds and the ability to consistently meet effluent limits. None of the pond managers cited odor as a problem since the ponds had been managed using ADS technology and were consistently well aerated. In the City of Hamel, homes are located 300 feet from the wastewater treatment pond and there have



LEGEND

Secondary Processes

Figure 2
FLOW SCHEMATIC FOR AN
AIPS POND SYSTEM
LOS OSOS WASTEWATER PROJECT DEVELOPMENT
SAN LUIS OBISPO COUNTY

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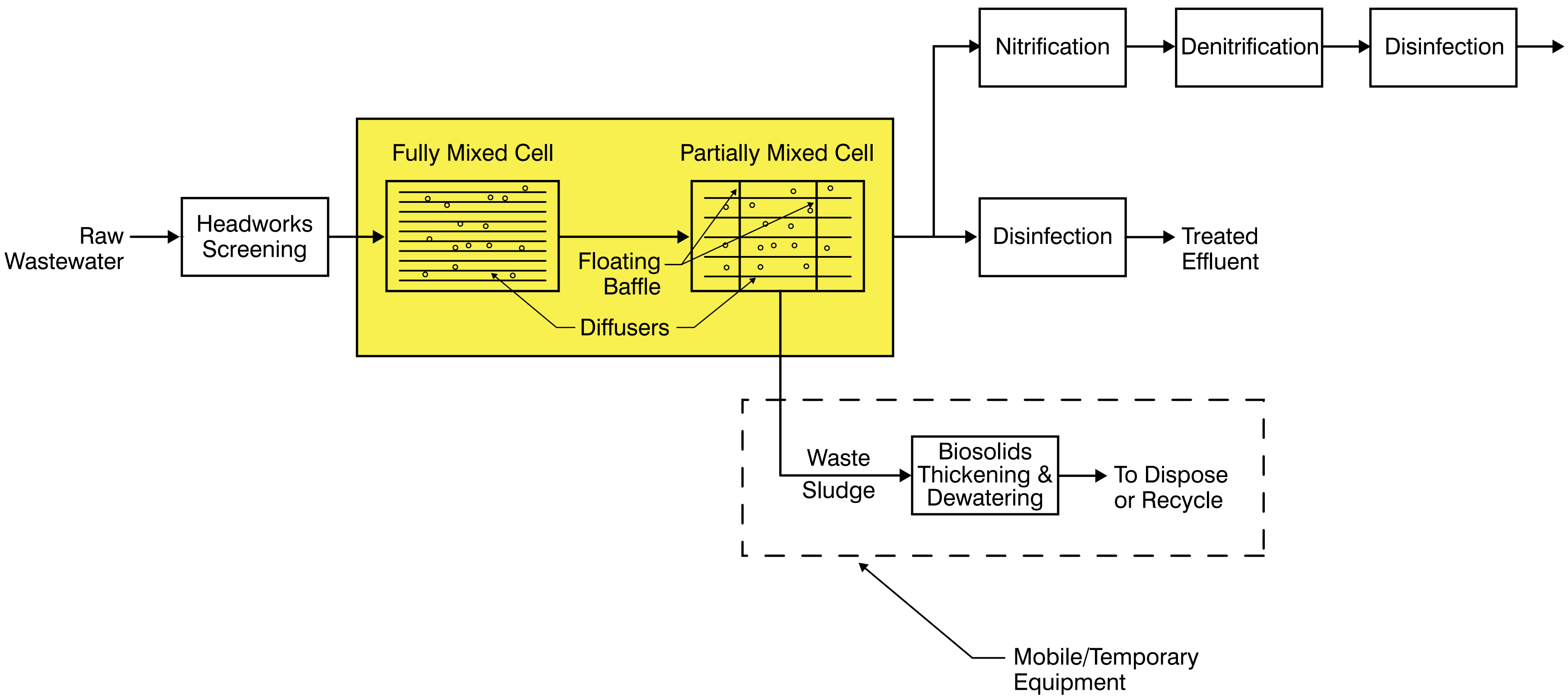

LEGEND

Secondary Processes

Figure 3
SCHEMATIC OF ADS/NELSON POND SYSTEM
LOS OSOS WASTEWATER PROJECT DEVELOPMENT
SAN LUIS OBISPO COUNTY

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been no complaints. None of the ponds have had their sludge removed, including the system in the City of Hamel, IL, which has been in operation for 59 years. ADS recommends using bacterial additives to help reduce solids accumulation. The utilities surveyed use these additives with apparent success.

Table 1 summarizes interview information provided by utilities managers with ADS aerated pond systems.

Table 1 ADS Aerated Pond System Reference Information
Los Osos Wastewater Project Development
San Luis Obispo County

City	Population Served	Year of First Operation	Effluent Quality[1]	Algae Blooms
Columbia, IL	9,918	2002	BOD 20 mg/L TSS 25 mg/L Ammonia 12-16 mg/L winter; nondetect summer	Sometimes in spring, effluent problems avoided with chem. addition [2]
Hamel, IL	1,200	1949[3]	BOD <5 mg/L TSS <1 mg/L Ammonia 10 mg/L winter; <10 summer	Sometimes, but no known effluent problems
Woodson, IL	559	Early 1970s[4]	BOD <10mg/L TSS <10 mg/L Ammonia 10 mg/L winter; <10 summer	Sometimes, but no known effluent problems

Notes:
(1) Observed pond performance. None of these utilities have nitrogen limits. They track ammonia concentrations because they believe that regulations are forthcoming. Columbia has Aquamats^{TM} (a synthetic attached biofilm) for nitrification and the other two cities have rock filters.
(2) Bacteria or copper sulfate added to alleviate algal blooms
(3) Managed with ADS technology since 1982.
(4) Managed with ADS technology since 2002.

4.0 COMPARISON OF PMFP ALTERNATIVES

The three PMFP alternatives have been developed using the flows and loads outlined in the TM on Flows and Loads (Carollo Engineers, February 2008). Table 2 provides a summary of the pond alternatives discussed in this TM. The estimates in Table 2 are shown for treatment of effluent for both a gravity collection system and a STEP collection system. Treatment requirements for a STEP system will be lower for all alternatives due to lower flows and loads being treated at the facility. The lower flows reduce the size of ponds, and the lower influent BOD concentrations reduce the aeration requirements, although much of the aeration demand is due to mixing requirements rather than oxygen transfer.

Table 2	Los Osos Pond Sizing and Energy Use Comparison Los Osos Wastewater Project Development San Luis Obispo County		
Type of Pond	**Footprint (acres) Gravity / STEP[1]**	**Depth (ft)**	**Secondary Treatment Energy Requirements (kWh/year) Gravity/STEP**
Facultative Pond[2]	>85	8[3]	None[4]
Partially Mixed Facultative Ponds			
DPMC Pond[5,6]	13 / 11	10	1500K / 1380K
AIPS Pond [7]	14 / 12	≤16 (avg. 12)	720K / 570K
ADS/Nelson Pond [8]	25 / 21	15	690K / 550K

Notes:
(1) Total facility acreage
(2) From Rich, L. “Low Maintenance Mechanical Simple Wastewater Treatment Systems.”
(3) From WEF “Natural Systems for Wastewater Treatment”.
(4) Assuming water moves between cells along a hydraulic gradient.
(5) Rich, L “Aerated Pond Technology, Technical Notes”
(6) Based on information from the City of Hollister “Long-Term Wastewater Management Program for the DWTP and IWTP.” The energy use in Hollister is greater that from Rich, L “Aerated Pond Technology, Technical Notes” (Note 5) because although the overall residence time is approximately the same, the completely mixed cells are larger and the partially mixed cells are smaller.
(7) Scaled up from Woodlands Mutual Company design info, provided by Wallace Group.
(8) From conceptual design provided by Air Diffusion Systems, Feb 2008.

Table 3 shows the cost of the different pond alternatives, assuming influent from either a gravity or a STEP collection system. These are the costs for only the secondary processes, as noted in Figures 1, 2 and 3. The costs are slightly different than those in Tables 4.9 and 4.10 of the Fine Screening Analysis because different design assumptions were used.

Table 3	Construction and O&M Costs for Different PMFP Secondary Processes [1,2] Los Osos Wastewater Project Development San Luis Obispo County			
Type of Pond	**Construction Cost - Gravity**	**Construction Cost - STEP**	**O&M Cost - Gravity**	**O&M Cost - STEP**
DPMC Pond	$2.4M	$2.3M	$430K	$420K
AIPS Pond	$3.3M	$3.1M	$360K	$340K
ADS/Nelson Pond	$4.4M	$4.0M	$350K	$330K

Notes:
(1) In February 2007 dollars, to be comparable to costs in the Fine Screening Analysis - line 3 in Table 4.9 and 4.10.
(2) Not including nitrification/denitrification

5.0 COMPARISON OF PMFPS TO OTHER TREATMENT OPTIONS

PMFPs are a feasible alternative to more technologically intensive wastewater treatment processes such as oxidation ditches and Biolac^{TM}. Biolac^{TM} and oxidation ditches have annual energy requirements of 1200 kWh and 1000 kWh for a gravity collection system, and 1000 kWh and 880 kWh for a STEP collection system. PMFPs are generally less energy intensive depending on the efficiency of the aeration devices (Table 2).

Effluent quality can be difficult to control in ponds, but with proper management and <u>additional treatment processes</u> to remove nitrogen and algae, effluent quality is comparable to that of oxidation ditches and Biolac^{TM}.

PMFPs require a larger area (up to 25 acres for Los Osos) than other types of wastewater treatment being considered for Los Osos. It is feasible to locate a site near Los Osos for ponds of this size, but the additional land area requirements need to be accounted for during cost estimation and environmental review. Other potential issues are odor control and algal blooms, but these can be minimized with appropriate management.

6.0 SUMMARY

PMFPs are a viable treatment technology for Los Osos. They generally have lower energy requirements than other treatment alternatives being considered. There are many types of facultative ponds, ranging from unmixed, where little energy is applied, to the ADS system, where additional bacteria is added to aid solids digestion and air is applied though diffusers. Nitrification/denitrification, algae control and disinfection will be important aspects of the design if a pond is chosen. While ponds have many advantages, their large footprint will likely make land acquisition more costly and more difficult to site.

7.0 REFERENCES

City of Hollister “Long-Term Wastewater Management Program for the DWTP and IWTP” December 2005.

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